The Relationship Between Sustained Attention and Rapid Automatized Naming Tasks

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ABSTRACT

Rapid automatized naming (RAN) tasks are potent predictors of reading abilities, but there is minimal evidence regarding what they specifically measure. In addition, attention is a critical component to cognitive processing and automaticity, factors which are crucial to reading ability. The purpose of this study was to examine the relationship between sustained attention and rapid automatized naming tasks, which was measured through the administration of assessments of word reading efficiency, phonological processing, sustained attention to response, and rapid automatized naming to 1st-3rd grade participants. Rapid automatized naming performance was predicted by phonological decoding and "GO" sustained attention to response accuracy performance. These results support the idea that sustained attention contributes to what RAN measures, identifying another factor in reading ability that can be targeted for testing and intervention.

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Chapter I

Introduction

Importance of Understanding Reading

Reading is a critical ability not only for childhood academic performance, but for its notable connections with greater success, health, and longevity in adulthood. For that reason, early identification of reading difficulties and disorders is crucial for timely intervention and remediation, especially before reading becomes the basis for learning in other academic subjects. While the underlying processes of reading comprehension have been theorized and can be assessed by various measures, rapid automatized naming tasks remain a strong predictor of reading ability—with little understanding of what it actually measures. Areas like phonological decoding have been connected to automatized naming performance in the past, but much else still remains unknown (Wolf & Bowers, 1999). In view of the fact that reading disorders are often comorbid with impairments at the attentional level, sustained attention may prove a potential contributor to automatized naming performance, and thereby reading ability as a whole.

Chapter II

Review of the Literature

Reading

According to the widely accepted Simple View of Reading, overall reading comprehension has been proposed as the product of two distinct processes—word reading and language comprehension (Kendeou et al., 2009). Word reading is the recognition of familiar words, while language comprehension is the actual understanding of those words through the process of decoding. Scarborough's reading rope further teases apart the elements that make up these two processes which ultimately weave together to accomplish reading comprehension, with language comprehension becoming more strategic, and word recognition becoming more automatic (International Dyslexia Association, 2018). Breakdowns in components that support overall reading comprehension can result in reading failure, an impairment which when left unremedied can have severe downstream effects. While narrowing down an identified reading disorder to specific areas of weakness through comprehensive measures is a valuable and necessary action to facilitate creation of targeted intervention, the ability to accurately predict reading weakness is equally as crucial. Early academic development depends greatly on a strong grasp of the processes that comprise reading as a whole, and therefore must be understood and measured accordingly.

Currently, the most potent of these predictive measures is the rapid automatized naming task, which is able to measure both the current reading abilities of older school

aged children and predict the future reading skills of younger children—even those who are still considered non-readers. The use of RAN has become commonplace in reading evaluation precisely because of its accuracy, and it has been the source of much research in relation to the model of reading processes as we currently understand them.

Word Reading

Word recognition is the combination of sight word reading, decoding, and phonological awareness. In the skilled reader, these separable components would work to make word reading a more automatic process so that higher-order skills are freed up for comprehension (Perfetti & Hogaboam, 1975). In essence, the reading for meaning that is derived from comprehension, relies on the efficiency of the reader's ability for decoding and recognizing text. Phenotypic studies have observed that word reading ability is an especially strong component in reading comprehension at younger ages and decreases in correlation over time (Betjemann et al., 2007). This can be attributed to the automaticity of word recognition and decoding ability that can manifest through successful instruction and supports efficient reading that frees up the cognitive load that allows processes to activate and connect with rapidly identified words.

Word reading on the surface may be fluently performed and mistaken for strong reading ability; however, it is only one of the two main processes that contributes to reading. In essence, fast and accurate reading is not necessarily interchangeable with efficient word recognition. Taken alone, the recognition and efficient decoding of words is insufficient for true reading as it fails to involve the cognitive operations which enable the reader to truly comprehend the text they decode. The simultaneously occurring cognitive domains which take place in the background during successful reading depend

on more than pure decoding and sight recognition abilities to work together. This is further evidenced by the fact that decoding abilities become less explicitly relied upon as readers progress through the development of reading skills. As the process becomes more automatic, the connection to text can become more robust.

Comprehension

Language comprehension is made up of background knowledge, vocabulary, language structures, verbal reasoning, and literacy knowledge. These elements are "higher-order," as they rely on cognitive processes like retrieval to take place efficiently so as not to disrupt the flow of reading, especially as decoding on the lower level becomes more automatic (Perfetti & Hogaboam, 1975). Retrieval during the course of reading may be drawn from various areas of the brain like memory stores and other multiregion associations to be recalled, visualized, and understood. Similar to word reading skill, the elements of comprehension must become strategic to support the young reader's transition from learning to read, to eventually reading to learn. This process is foundational for understanding more complex concepts and procedures. For example, word problems in mathematics and sciences are dependent on efficient and comprehensive reading ability as a gateway for solving or working through the relevant content. Although one could present with relative strengths in decoding and word recognition, deficits in comprehension inhibit the connection to words and their associations needed for strong reading ability.

The success of strategic comprehension depends on the efficiency of all neural processes at the same time. The ability to activate some volitional areas—like attention—

while inhibiting unwanted domains like perception to auditory or visual stimuli, is a necessary skill for fluent and undisrupted consumption and comprehension of text. Foundationally, strong stores for memory along with efficient processing to access these stores in a timely and appropriate manner underpins the overall background operation that comprehension relies upon. Nouwens et al. studied the storage and processing of phonology and semantics for reading comprehension with a control for existing decoding and vocabulary skills (2016). The findings of their study established that semantic working memory was most indicative of reading comprehension variations, and that semantic storage along with processing abilities was more indirectly influencing reading comprehension. While working memory has already been indicated in this way for adult readers, it had not been previously established in typically developing children. As such, these findings further demonstrate not only the reliance on fluent word reading to support comprehension, but also the foundations of cognition as a prerequisite for strong reading skill.

Reading Disorders

A breakdown in the reading process may take place in one or more of the many contributing elements that make up the key components of reading. This poses a problem for the identification of these breakdowns within a timely manner, as these elements are so closely intertwined that a deficit in one area may be both contributing to and resulting from deficits in another. These deficits can manifest as reading disorders like dyslexia, which can carry lifelong negative effects if left untreated. Compounding this issue is the fact that the identification of reading failure is often later occurring, at times years after maladaptive reading habits have been formed. Thus, it is important to gain a greater

understanding of reading disorders and the measures that are able to predict them. Intervention has been shown to be far more effective if implemented during these early years.

Incidence and Prevalence. Worldwide, 3-11% of children and adolescents are identified as having reading and/or spelling disorders, classified by isolated reading and spelling disorder (prevalences of 6% and 7%, respectively) and a combination of the two with a prevalence of 8% (Galuschka & Schulte-Körne, 2016). The reading disorders by this classification are characterized by many errors made in reading, slowed reading speed, and problems with comprehension. More granularly, clear distinctions can be made among these signs of reading disorder, where problems in decoding are labeled as developmental dyslexia, and problems in comprehension as reading comprehension impairment (Hulme & Snowling, 2016). Due to the nature of dyslexia specifically, diagnosis of the disorder often occurs much later in life, even though risk factors and comorbidities have been identified. Dyslexia tends to run in families, is more prevalent in males, and is often comorbid with other developmental disorders like attention deficit hyperactivity disorder (Hulme & Snowling, 2016). However, because the disorder becomes more apparent at the point that skilled reading should have already been acquired—like in the early elementary years—the diagnosis is often given once reading failure is already evident.

Though dyslexia has become the popular title for reading failure, it is a title made to describe patterns of phonological strengths and weaknesses without necessarily delineating the reasons why the phonological deficit exists. As Stein explains, understanding the neural pathways that result in poor development of phonological skills

is useful for identifying it in the future, and highlights the auditory-temporal processing impairments that have been identified in people with dyslexia (2022). Of course, this is a single area of weakness among many that are suspected of impeding not only the discrete trials of reading, but the cognition that occurs outside of it which is necessary for building up the components that support reading. With these poor foundations, reading failure—and specifically dyslexia—may be the end result of a cascade of weaknesses.

Effects of Reading Failure. The effects of reading failure are numerous and well-established, making early detection of these deficits crucial. On the individual level, reading failure is associated with unemployment, lower income, lower quality jobs, harmful health behaviors, decreased self-esteem, and lower life expectancy (Lal, 2015). Cognitively, illiteracy as a result of reading failure even impacts the brain's function and architecture, affecting numerous cognitive processes that the adult brain relies upon (Ardila et al., 2010). Societal impacts are especially evident when these manifestations of reading failure are taken into account. Reductions in GDP, community involvement, and civic participation have been observed in societies with low literacy (Lal, 2015). The push for early identification of variables that predict reading failure is therefore well justified, especially when the short timeframe of early elementary age is considered.

More immediately, in the early elementary age, effects of reading failure can be felt at the socio-emotional level in developing children. As curriculum grows more advanced and dependent on reading skill for comprehension and solvability, children grow more aware of their weaknesses in reading and begin to express signs of maladjustment as a result (Morgan et al., 2012). It is also reported that poor reading skills has negative impacts on reading related motivation and attitudes. Branching from these

attitudes are the self-image effects that children then adopt as a result of being poor readers.

As children become more aware of their deficits they begin to engage in avoidance behaviors toward reading tasks and reduce their participation in reading activities both in the classroom and at home (Morgan et al., 2012). This only compounds the issue as attempts at intervention for these deficits are less effective when children lose motivation or desire to even attend or participate in remediation tasks. Because schooling rapidly begins to involve reading as a prerequisite for developing knowledge and application in other subjects, children become constantly reminded of the difficulty they experience when reading. As early intervention is understood to be a strong prognostic indicator for improving areas of weakness, the developing child's understanding of how far this weakness extends in their daily academic life could potentially become a large obstacle to targeted intervention that runs parallel with potential age-related reductions in neuroplasticity. This further necessitates going beyond early intervention, highlighting the importance of early prediction of future deficits. Understanding the areas that contribute to this predictability can be instrumental in identifying children early to improve reading outcomes before children are faced with the demotivating effects of reading failure.

Assessment of Reading

Due to the various contributing factors toward reading skill, the assessment of reading is typically broken down into separate measures targeting these elements individually. Measures of naming speed are also acquired in addition to the established components, working together to determine reading skill, and the specific areas where deficits are present.

The collection of measures obtained for a comprehensive reading evaluation generally involves accuracy of single word reading and comprehension. More specifically, the abilities to recognize and decode single-words and comprehending texts, as they are the culmination of their constituent parts working together. Additionally, measures of vocabulary are included along with phonological and phonemic awareness measures. These measures assess the more background—yet no less closely entwined—areas that influence the accuracy of word reading and comprehension, like semantic concepts and relationships and mastery of a language's sound system. Measures of reading fluency are additionally administered to assess the rate at which these processes successfully work together to accomplish efficient and comprehensive reading abilities.

Single Word Accuracy. Single word reading is often measured by having a participant read from separate lists of words. The sight words are those which the participant should be able to recognize upon seeing them, due to their familiarity and ubiquity. These words also include words with irregular spelling patterns which do not necessarily follow the rules that would allow a reader to decode them accurately. As such, identifying these words upon sight alone is most efficient for reading. Additionally, pseudowords are those which require decoding skills and orthographic pattern recognition to be read and represent the unfamiliar words or word parts that a reader may encounter as their lexicon expands.

Comprehension Accuracy. Reading comprehension can be assessed in a variety of ways, including normreferenced tests which typically contain text-based and inferential questions, informal reading inventories where the test administrator asks more open-ended passage-related questions, interviews and questionnaires of reading

behaviors, observations, free-writing activities, oral retelling tasks, and freewriting tasks (Klingner, 2004). While all options yield slightly different types of results, and have different demands of the administrator, Klingner (2004) argues that regardless of the selected method, the material provided to the student should be at their instructional level, as fluency marked by an inability to read at least 95% of the given words will hamper comprehension of the text. This is rather intuitive as slow, effortful reading may result in accurate word reading, but poor comprehension as more cognitive burden is being directed to lower-level skills.

Vocabulary. Assessment of vocabulary is quite straightforward with measuring semantic meaning, but other aspects of vocabulary may also be targeted, like synonymy, polysemy, and collocation (Qian & Schedl, 2004). Words are not purely orthographic or phonologic representations, and so mere decoding or identification of a word is not sufficient for comprehension if the word lacks cognitive-linguistic associations for language processing, like meanings, symbols, and qualitative concepts. Qian and Schedl (2004) observed that performance on vocabulary measures is significantly related to performance on reading comprehension assessments and is similarly predictive of reading test performance. Thus, vocabulary measures can add to the picture of a test-taker's reading abilities both individually and as context for other related cognitive domains and processes.

Reading Fluency. Automaticity of reading is the goal for overall comprehension, and the transition of reading into a tool by which other academic skills may be acquired. Fluency is a good measure of automaticity as it combines speed, effortlessness, autonomy, and lack of conscious awareness necessary for efficient reading, which forms

the basis for adequate comprehension (Kuhn et al., 2010). In essence, fluency is a marker of smooth interaction of all necessary reading components at their various levels of processing. To measure this, oral reading of connected text can be assessed, and used to inform instruction, based on prosody, rate, and accuracy, as extreme variations in these can reduce reading comprehension. This is especially important as some children with dyslexia have been known to dissociate between accuracy and rate performance at the word level (Katzir et al., 2006). The RAN task has especially been thought to be most predictive of reading fluency as it inherently measures rate and accuracy as they work in tandem. As a combination of many of the processes important to reading, fluency plays a measurable role in the understanding of dyslexic performance.

Phonological and Phonemic Awareness. Tests of phonological and phonemic awareness often measure such concepts as elision, blending, and phoneme isolation abilities. These concepts require a person to be able to mentally hold, process, and manipulate auditory information. Mastery of a language's phonology is well established as a foundation to reading ability, as the cognitive areas of spoken language are especially active in the early stages of reading acquisition (Goswami, 2008). Mastery of phonological rules supports independent ability to decode accurately and efficiently. Clinically, phonological awareness has not only been linked to reading disabilities, but also as a factor predictive of reading ability until 2nd grade (Hogan et al., 2005). This is not surprising as it was previously noted that the age at which reading disorders are usually identified is in that same time frame that reading ability should already be established. This further necessitates the need for early identification.

Past the early elementary school stage, however, reading ability shifts from dependence upon phonological abilities, yet it is no less critical in reading function as it utilizes cognitive processes similarly to those that enable comprehension to take place. The efficient operations of processing, working memory, and attention play an important role in facilitating the ability to not only have knowledge of a language's phonology, but also the ability to manipulate it. To complete a phoneme isolation task, for example, may require the listener to point out the second sound in a given word like "island." Upon hearing this word, the listener may call to mind an orthographic representation of the word and begin activating auditory and spoken language channels to mentally sound the word out. Then, to isolate the second sound, /l/, would require the listener to not only manipulate the word in such a way that they associate the sounds with a number sequence, but they must also then inhibit the orthographic representation they have recalled to recognize the second sound (/l/) and not the second letter ("s"). This entire process depends on efficient processing and working memory to activate these channels in enough time while holding onto information to then manipulate, and requires attention to be sustained for the duration of the task in order to avoid disrupting its progress. In this way, poor phonological skills do not just represent poor decoding abilities, but also rely on processes which, when impaired, can negatively impact the ability to read as a whole.

Rapid Automatized Naming. Rapid automatized naming, also known as RAN, is a skill which is not an element present in the simple view of reading yet acts as a potent predictor of reading ability, as it reveals the automaticity crucial to fluency. RAN tasks require a child to name all stimuli in a given array as quickly and accurately as possible, and are thought to require the same cognitive processes as reading, including:

> (a) attention to the stimuli; (b) visual processes that are responsible for initial feature detection, visual discrimination, and letter/letter-pattern identification; (c) integration of visual information with stored orthographic and phonological representations; (d) lexical processes, including access and retrieval of phonological codes; and (e) organization of articulatory output. (Araújo et al., 2015, p. 2)

Although RAN is one of the best predictors of reading ability, reasoning for its contribution is not fully understood. Neural correlates have been found to associate RAN performance with many of the brain regions activated during reading, but it is still unknown if that is the basis for its ability to predict reading performance (Misra et al., 2004). RAN has regardless been a crucial measure in detecting reading disability. Wolf and Bowers (1999) established a hypothesis to describe the role of naming speed in this scenario, with naming speed deficits seen as a marker of lower-level processing problems impacting fluency, or as a manifestation of general processing speed impairments that impact the elements of reading. While these explanations help to describe the possible nature of the problem that RAN helps to identify, the concept of what RAN measures is not entirely known. Interestingly, a study assessing processing speed deficits in both ADHD and reading disability found that the RAN task deficits exhibited by those with reading disability were better explained by poor processing speed than by phonological weaknesses (Shanahan et al., 2006). While both ADHD and reading disability share deficits in processing speed which RAN appears to detect, processing speed does not operate without other cognitive influences, like attention, which RAN may also be able to observe.

Processing and Encoding

Poor reading ability is closely related to deficits in attention and other similar processes like memory and processing (Shanahan et al., 2006). On the surface, a simple model of comorbidity may be assumed to better understand the relationship between reading disability and attentional impairments; however, current findings suggest a bit more nuance. As Shanahan et al. posit, poor processing speed is a shared cognitive risk factor between reading disability and ADHD; they report the recent findings of shared cognitive domains between the two disorders—most prominently being processing speed. Shanahan et al., define processing speed as the underlying combined process of integrating the lower-level perceptions with higher-level cognition and go so far as to report that this deficit is much larger in reading disability than even ADHD alone (2006). This definition of processing speed is remarkably similar to the process of simultaneous integration required in reading comprehension, outlining the importance of multiple gateways and paths by which cognition takes place to support fluent reading. Additionally, the processing that takes place during reading depends on the working and long-term memory of the reader. As the aforementioned model of comprehension explains, comprehension is dependent on constant retrieval where the reader not only decodes the words they see, but rapidly accesses the words' associations and meanings stored in long-term memory. This retrieval is a constantly active process of recall, manipulation, and application all while continuing the reading task. As such, measures of working memory are identified to be crucial in measures of coding tasks precisely because they require the sustained attention necessary to complete a task while mentally manipulating and recalling information at the same time (Jacobson et al., 2011).

Long-term memory is another area in which the downstream deficits of attention can be noticed. The long-term memory from which the reader recalls relevant knowledge activated by fluent text reading is dependent on attentional state for encoding information (deBettencourt et al., 2021). Specifically, deBettencourt et al. explain that the fluctuations of sustained attention contribute greatly to what information will ultimately be encoded for later recall (2021). In this way, deficits in attention can impact reading not only directly while attending to a task such as reading, but indirectly as well through the formation of a less robust long-term memory store to pull from when reading. Furthermore, Kibtoby et al., reported support for the hypothesis that efficiency of visualperceptual task completion—which depends on processing speed-- can be impaired by inattention (2020). This points toward the heavy reliance on attention to assist in processing and working memory to achieve fluent and automatic reading for true comprehension.

Sustained Attention. Sustained attention can be differentiated from other forms of attention by its "focus on performance on a single task over time, with the goal of explaining both the fluctuations within an individual as well as the individual differences in overall ability to maintain stable task performance" (Esterman & Rothlein, 2019, p. 174). This type of attention is characterized by automaticity in the sense that a more automatic—or less difficult—task results in more sustained attention allocated to that task. Esterman and Rothlein (2019) have found that fluctuations in sustained attention (like those found in ADHD) are associated with failures in working memory and long-term memory encoding.

These cognitive processes are likewise crucial to the skill of reading through immediate impacts on maintaining task attention to support active phonological and comprehension processes, and distally by reducing the amount of information which is held onto and stored in relevant brain regions for ready access. As deBettencourt et al. (2021) explain, sustained attention is a separate construct from working memory but is nonetheless closely linked. Fluctuations of sustained attention are indicated as a strong influence over what information is ultimately stored and able to be recalled. This relationship was able to be predicted by deBettencourt as upcoming presented items in a given presentation were predicted to be remembered or not in the future based on EEG detected fluctuations of sustained attention, regardless of whether the participant was cued to the item presented. This finding was able to separate sustained attention from spatial attention for the sake of deBettencourt's study, but offers potential insight into the impact of sustained attention in a reading task. Despite being cued to a text through spatial means, impaired sustained attention abilities may persist regardless, leading to attentional fluctuations during reading that impact fluency. On a direct level, changes in attention itself are not conducive to efficient, and undisturbed reading fluency, the underlying automatic process of which RAN has been frequently shown to uncover.

Purpose

The purpose of this study is to measure the relationship between sustained attention and rapid automatized naming tasks. Although RAN is related to fluency, the only other currently verifiably identified contributors to RAN performance have been phonological awareness, sight word reading, and phonological decoding. The relative contribution of sustained attention to RAN performance has not been assessed but affects

many of the aspects of fluency that are crucial to reading ability. Additionally, the comorbidity of attention deficit disorders and dyslexia offers additional support to the idea that attention may play an important role in reading failure. As RAN has already been used to identify processing speed deficits in both those with ADHD and reading disability, there are underlying cognitive domains that have impacts on attention and memory generally, but also more specifically as they pertain to reading. To assess the extent of a relationship between attention and the predictive nature of reading deficits by RAN assessment would provide not only greater understanding of what RAN measures but would also supply another metric by which reading ability could be predicted. This could not only be clinically useful in the early identification of reading failure but could also be useful in the development of individualized instructional/intervention plans for those who struggle with reading. Thus, if there is a relationship between sustained attention and rapid automatized naming tasks, to what extent does this relationship correlate?

Hypothesis

It is hypothesized that there will be a relationship between sustained attention and RAN tasks to the degree that RAN performance will be predicted by sustained attention performance. Due to the association between attention deficit disorders and reading disability, as well as the impact of sustained attention on fluency-related processes that RAN is able to uncover, it is proposed that RAN and sustained attention will be found to relate to one another.

Chapter III

Methods

Participants

Institutional Review Board approval was first obtained to conduct research with children, and university approval may be found in Appendix A. This study involved participation of 20 participants between 1st and 3rd grade, including 12 males and 8 females. The average age of these participants was 7 years; 5 months, within a range of 6 years; 5 months to 9 years;11 months. All participants were recruited through informational flyers distributed to local childcare centers and extracurricular tutoring centers, in addition to the Speech and Hearing Clinic and Scottish-Rite Literacy Program at Valdosta State University. Incentives for participation included a digital gift card of the participant's choice, and free reading evaluation scores provided to parents.

Procedures

Parents were provided with a consent form to inform them of the nature of evaluation for their child, and the children were read an additional verbal assent form (see Appendices B and C). The tasks to be completed by the participants included the Test of Word Reading Efficiency- Second Edition (TOWRE-2) (Torgeson et al., 2012), the Phonological Awareness battery of the Comprehensive Test of Phonological Processing- Second Edition (CTOPP-2) (Torgeson et al., 2013). Additionally, RAN digit and letter naming tasks were presented as part of the CTOPP-2. These measures were

recorded using paper-pen protocols, aside from a computer-based sustained attention to response task (SART).

The TOWRE-2 requires that participants read from two lists of words progressing in difficulty for 45 seconds each—one containing sight words and the other, pseudowords—which yield an overall word reading efficiency score based on the amount of words read correctly within the given timeframe. This measure pulls in the word recognition and decoding skills that make up the single-word reading component of the fluent reading. Additionally, the timed aspect of this measure places added constraint on the participant which has been connected with processing and attentional burden (Kibby et al., 2019). Altogether, this measure will serve in the present study as a known existing correlate with RAN performance to compare SART performance against.

The CTOPP-2 subtests of elision, blending words, and phoneme isolation make up the Phonological Awareness battery and require that the administrator give the participants untimed phonological tasks of progressing difficulty to measure overall phonological processing ability. Tasks of elision involve presenting words to the participant and asking them to remove a syllable or sound, and to provide the new, manipulated word. Blending involves providing the participant with segmented parts of a word for them to repeat back to the administrator altogether as the complete word. Phoneme isolation is the previously mentioned skill that requires the participant to say the requested sound in a specific location of a given word. The letter and digit RAN arrays of the CTOPP-2 provide separate times for how long the participants take to read all presented items, and together yield a combined composite score of RAN performance, which has been implicated in the past with the decoding abilities previously mentioned.

While the RAN letter task is more closely predictive of reading fluency, both arrays provide insight into the fluency of processing and output of the participant (Shanahan et al., 2006). This ability to manipulate the sounds of the participant's sound system is the foundation which underpins the decoding efficiency and accuracy that the TOWRE-2 is able to uncover, and it relies on efficient working memory and attention to successfully complete

The SART task administered provides scores for "GO" and "NO-GO" errors, "GO" and "NO-GO" accuracy percentages, latency scores, and mindfulness scores, based on the participants' ability to pay attention and respond to the series of 223 numbers that were randomly displayed in succession in the middle of the screen in 86 point Times New Roman font. The rate of the number presentation was controlled through SuperLab with a stimulus being displayed every 1100 milliseconds. When the number 3 was observed, the participant was instructed to press the space bar, with a total of 31 threes being presented during the task. When presented with a question asking if the participant was paying attention, the Y or N keys were to be pressed to reply with "yes" or "no" to determine mindfulness scores. These procedures were all counter-balanced across all participants to control for any fatigue effects.

Measures

Test of Word Reading Efficiency-Second Edition

The TOWRE-2 sight word reading and phonological decoding subtests yield normative age-based scaled scores (average range = 85-115). These provide a combined total word reading composite score, the TOWRE Index (average range = 85-115). The TOWRE-2 has a mean of 100 and standard deviation of 15 for all yielded scores.

Comprehensive Test of Phonological Processing-Second Edition

Age-based scaled scores (average range = 7-13) on the elision, blending words, and phoneme isolation subtests of the norm-based CTOPP-2 provide an overall phonological awareness composite score. Additionally, the RAN subtests of the CTOPP-2 provide a RAN composite score based on combined length of time to complete the individual arrays. Similar to the TOWRE-2, the CTOPP-2 has a mean of 100 and standard deviation of 15 for all scores.

Sustained Attention to Response Task

The sustained attention to response tasks (SART) provide scores for "GO" accuracy and "NO-GO" accuracy as percentages, to denote the accuracy of the participant in pressing or not pressing the space bar in response to appropriate stimuli. A "GO" latency score measured in milliseconds is also provided as a measure of how long it takes to activate the participant's "GO" response.

Analysis

Using the scores provided by all measures, a step-wise linear regression analysis was applied along with Pearson product-moment correlations analyses to determine correlation coefficients for the measures previously associated with RAN-- such as sight word reading and decoding fluency, elision, and phoneme isolation-- in addition to the scores obtained from the SART tasks. The correlation coefficients were utilized to indicate whether RAN performance was able to be predicted by the performance on those additional measures.

Chapter IV

Results

As part of this study, twenty participants were obtained and administered the TOWRE-2, CTOPP-2 PA, CTOPP-2 RAN, and SART tasks in order to answer the experimental question which asked to examine the relationships between sustained attention, RAN, phonological decoding, sight word reading, and phonological awareness. Table 1 displays the means and standard deviations for all experimental measures. Individual participant data for all measures can be found in Appendix D.

Table 1

Means and Standard Deviations of all Experimental Measures

	Mean	**Standard Deviation**
RAN (μ=100; σ=15)	89.35	11.82
	76.33	13.37
SART GO (Accuracy Percentage)	96.59	2.27
SART NO-GO (Accuracy Percentage)	734.11	80.76
SART Latency (Seconds)	91.05	21.36
TWRE SW (μ=100; σ=15)	89.70	21.36
TWRE PD (μ=100; σ=15)	90.05	21.76
TWR Comp (μ=100; σ=15)		

	8.15	2.28
CTOPP EL (μ=10; σ=3)		
	8.00	2.47
CTOPP BW (μ=10; σ=3)		
	8.10	2.29
CTOPP PI (μ=10; σ=3)		
	88.40	11.86
CTOPP PA (μ=10; σ=3)		

Correlations

No violations in terms of skewness or outliers were noted. In addition, no missing data was present. Correlation coefficient values are presented in Table 2. Significant correlations were found between RAN and the following: SART "NO-GO" accuracy, sight word Reading, phonemic decoding, overall word reading fluency, elision, phoneme isolation, and overall phonological awareness.

Table 2

Summary of Correlations Between Measures

	RAN	GO %	NO-GO%	Lat.	SW	PD	TWRE Comp	EL	BW	PI
RAN	1									
SART GO%	.331	1								
SART NO-GO%	.471*	.392	1							
SART Lat.	-.402	-.687*	-.465*	1						
TWRE SW	.710**	.341	.101	-.455*	1					
TWRE PD	.721**	.197	.051	-.351	.895**	1				
TWR Comp	.734**	.275	.077	-.409	-.973**	.974**	1			
CTOPP EL	.538*	.267	.221	-.439	.614*	.688**	.672**	1		
CTOPP BW	.297	-.084	-.022	.083	.237	.435	.344	.337	1	
CTOPP PI	.504*	-.117	-.056	.074	.245	.404	.331	.330	.725**	1
CTOPP PA	.546*	.016	.048	.109	.45	.63**	.554*	.68**	.862**	.856**

*Correlation is significant at the 0.05 level (2-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

Regression

In addition, significant findings were obtained via the stepwise linear regression analysis to predict RAN performance. RAN performance was reliably predicted using the TOWRE-2 composite, SART "NO-GO" percentage, and phoneme isolation scores being entered into the equation, $F\,(3, 16) = 22.62$, $p < .001$, $R^2 = .809$, $R^2_{Adjusted} = .773$).

Chapter V

Discussion

While what RAN measures is not entirely understood, its accuracy in predicting reading abilities is nonetheless potent. Understanding the RAN tasks' relationship with reading can prove especially useful to timely identification of potential reading difficulties, allowing a clearer perspective of all the components that make up the process it measures. While previous studies, as well as the current study have determined that measures of phonological ability are connected to RAN, the data obtained in the present study supports the hypothesis that sustained attention is also a contributing factor to RAN performance.

While sustained attention has not been measured before in the context of RAN, evidence surrounding sustained attention and its relative deficits in attentional disorders—which are often comorbid with reading difficulty-- has been consistent with the results obtained in this study. The automaticity that underlies fluent and efficient reading is a key feature of sustained attention as Esterman and Rothlein (2019) have defined it, supporting the idea that disruption in sustained attention may likewise disrupt reading flow and comprehension. Additionally, the significant correlation between RAN performance and phonological measures is consistent with existing evidence of this relationship, further supporting the claim that RAN is able to measure phonological abilities. Wolf and Bowers (1999) observed the breakdowns in this relationship as

potentially being caused by processing speed deficits that impact reading fluency, which when combined with the understanding of sustained attention disruption resulting in slower processing and impaired encoding and working memory abilities, aligns with the findings of this study that indicate a close correlation between sustained attention and phonological decoding ability on RAN performance.

It was unsurprising that sustained attention would be in close relationship with RAN performance, as the comorbidity of attention deficits and reading disorders is well established. However, understanding the additional deficits of attentional and reading disorders beyond just attention and phonological abilities was the unexplored area that RAN performance was able to shed some light on. Dyslexia has, with time, been popularly simplified to its general area of weakness—phonological abilities. This has somewhat resulted in a reduced consideration for the underlying factors that may contribute to successful reading. In reading, it may be simpler to note that reading is a multivariable process with an end-result that must be fluent to be effective, and breakdowns in one or more areas may result in reading failure to various degrees. Even simpler is to draw the conclusion that disorders of attention often co-occur with reading failure, and the attention deficits may be an etiological source of that reading failure. The present study pushes back on this notion by emphasizing the connections of attention and phonological abilities as going beyond their immediate effects.

It must be understood that sustained attention and phonological skills are singular cogs in a complex machine that accomplishes more than just reading fluency in its most direct application. Sustained attention is an ability that supports the functions of cognition that must be present even before beginning a reading task, as it affects what is encoded in

the areas from which language comprehension draws. Similarly, phonological skills represent the cognitive ability to use sustained attention to support the holding and recall of information to be mentally manipulated and placed in that memory storage to support decoding and recognition. Both of these elements that RAN reliably predicts go deeper than influencing the direct task of reading through mere decoding deficits or an inability to maintain attention on the text. RAN uncovers the very fluency of cognition required to create the fluent reading that it measures.

Implications

The societal and personal effects of reading failure necessitate a timely identification of those factors which contribute to the breakdown of reading. While RAN is a strong predictor of reading ability, understanding what it measures is an important component in identifying those contributing factors and providing intervention accordingly. Though it has been connected to various components that build to reading fluency, the area of attention has been suspected yet unmeasured. While reading has been more recently conceptualized through the analogy of a reading rope comprised of intertwining linguistic processes, there is yet more to uncover within the cognitive processes that support them, sustained attention being just one of them. By establishing the extent of the RAN and sustained attention relationship, researchers can begin to explore those areas that impact reading fluency beyond the widely accepted view of a predominantly phonological deficit basis for reading disorder.

As sustained attention has never been empirically identified as a contributor to RAN before, its correlation now provides another factor that can reliably signal potential reading deficits. Early intervention for reading disorder is crucial for making foundational

gains before classroom instruction begins to outpace a slower developmental progression which can greatly increase academic burden. Early intervention must especially be implemented in a timely manner that reduces the academic and socioemotional impact on elementary-aged children, as well as the potential life-long impacts that reduce quality of life and societal outcomes.

Clinically, observation of poor sustained attention allows for another avenue in which identification of reading failure is possible. Though it is not specific enough to be the driving element of a targeted intervention, it reveals another element of reading failure that the oft-recommended phonological intervention may not touch. Understanding sustained attention and its relation to processing and encoding provides a broader picture of the components that underlie reading failure that RAN is able to measure and predict. As such, poor RAN performance presents a necessity for further evaluation to uncover the areas of weakness to be treated, and not purely as a marker of phonological deficits.

Limitations and Recommendations

The use of twenty participants' data points was a constraint that must be considered in the results of this study. The background of these participants must also be considered as some participants were bilingual—specifically in Hindi—which is not an orthographic language the same way that English is. Though they were fluent English speakers, the effects of development of bilingualism in an orthographic and nonorthographic language may have undetermined effects on phonological and RAN ability due to possible differences in processing and representations. Additionally, the academic instruction common to the area from which the participants were drawn may

impact results insofar as targeted skills may create common patterns of strengths and weaknesses among the participants. While the methodology of this study was strong, a larger data set would provide more representative results for the population to which it applies. In the future, it is recommended that more data be collected using these methods in order to create a more well-rounded view of the RAN and sustained attention relationship. If the results remain strong, then recognizing sustained attention as a contributor to reading performance becomes crucial in more specific and effective identification of reading difficulties. Additionally, understanding the closely entwined nature of sustained attention with processing speed and memory encoding, further research into RAN and these cognitive processes may help to support the currently accepted hypothesis suggesting such links.

Conclusion

The significance of a sustained attention and RAN relationship lies not only in the fact that it has never been measured before, but in its ability to broaden the understanding of what RAN measures. The potency of RAN is undisputed in predicting reading abilities, and clarifying the components that contribute to it offers more areas to measure for identifying reading failure, as well as remediation targets so that reading ability is strengthened in those critical years where its automaticity becomes necessary for literacy.

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Appendix A:

Institutional Review Board Approval

Institutional Review Board (IRB)
for the Protection of Human Research Participants

EXPEDITED PROTOCOL APPROVAL REPORT

Protocol Number: 04426-2023

Responsible Researcher: Dr. Matt Carter

Co-Investigators: Taylor Fries & Mary Allison Moody

Project Title: *The Relationship between Naming Speed and Sustained Attention.*

Level of Risk: ☒ Minimal ☐ More than Minimal

Type of Review: ☒ Expedited ☐ Convened (Full Board)

Approval Categories: 6 & 7

Approval Date: 07.10.2023

Expiration Date: 07.10.2026

Consent Requirements:

- ☐ Adult Participants – Written informed consent with documentation (signature)
- ☐ Adult Participants – Written informed consent with waiver of documentation (signature)
- ☐ Adult Participants – Verbal informed consent (Research Statement)
- ☐ Adult Participants – Waiver of informed consent
- ☒ Minor Participants – Written parent/guardian permission with documentation (signature)
- ☐ Minor Participants – Written parent/guardian permission with waiver of documentation (signature)
- ☐ Minor Participants – Verbal parent/guardian permission
- ☐ Minor Participants – Waiver of parent/guardian permission
- ☐ Minor Participants – Written assent with documentation (signature)
- ☒ Minor Participants – Written assent with waiver of documentation (signature)
- ☐ Minor Participants – Verbal assent
- ☐ Minor Participants – Waiver of assent
- ☐ Waiver of some elements of consent/permission/assent

Approval: This research protocol is **approved.** Your approved consent form(s), with IRB approval stamp are attached. If you prefer the original stamped consent, please email tmwright@valdosta.edu and the form will be sent via inter-office mail, or you may come by the OSPRA office to obtain the original. Please see page 2 for additional information for researchers.

Comments:

Elizabeth Ann Olphie 07.10.2023

Elizabeth Ann Olphie, IRB Administrator Date

Thank you for submitting an IRB application.

Please direct questions to irb@valdosta.edu or 229-253-2947.

Appendix B:

Institutional Review Board Parent Consent Form

VALDOSTA STATE UNIVERSITY

Parent/Guardian Permission for Child's/Ward's Participation in Research

You are being asked to allow your child (or ward) to participate in a research project entitled "*The Relationship between Naming Speed and Sustained Attention.*" This research project is being conducted by Matt Carter, a faculty member in Communication Sciences and Disorders at Valdosta State University as well as Taylor Fries, a student at Valdosta State University and Mary Allison Moody, a student at Florida State University. The researcher has explained to you in detail the purpose of the project, the procedures to be used, and the potential benefits and possible risks to your child (or ward). You may ask the researcher any questions you have to help you understand this study and your child's (or ward's) possible participation in it. A basic explanation of the research is given below. From this point on in this form, the term "child" is used for either a child or a ward. Please read the remainder of this form carefully and ask the researcher any questions you may have. The University asks that you give your signed permission if you will allow your child to participate in this research project.

Purpose of the Research: This study involves research. The purpose of the study is to investigate how sustained attention affects your child's reading ability.

Procedures:
You will be asked to complete a quick questionnaire about your child's attention and speech-language abilities. Your child will first have to complete a vision screening. After they have passed the screening, they will complete five different tasks. Two tasks consist of reading a list of letters or numbers quickly. One task consists of reading a list of words quickly. The fourth task requires your child to identify and manipulate units of the spoken language – parts such as words, syllables, and sounds. The last task will require them to press a button when they see certain objects appear on the computer screen.

Their participation will last approximately 30 minutes. They may discontinue at any time for whatever reason. All direct interaction with your child should occur either at the VSU Speech and Hearing Clinic, during their regularly scheduled speech therapy time, or during their summer/after school program. There are no alternatives to the experimental procedures in this study. The only alternative is to choose for your child not to participate at all.

Possible Risks or Discomfort Although there are no known risks to your child associated with these research procedures, it is not always possible to identify all potential risks of participating in a research study. However, the University has taken reasonable safeguards to minimize potential but unknown risks. By granting permission for your child to participate in this research project, you are not waiving any rights that you or your child may have against Valdosta State University for injury resulting from negligence of the University or its researchers.

Potential Benefits: Parents will have access to all of their child's testing results which can serve as a screener of overall literacy abilities. In addition, you will be able to sign for your child to receive a $10 gift card once they complete the testing. If you have further concerned regarding your child's reading abilities after their participation, then appropriate referrals can be provided.

Costs and Compensation: There are no costs to you or your child. There is a $10 gift card reward for your child's participation in this research project. You must sign for your child to receive the gift card.

Assurance of Confidentiality: Valdosta State University and the researcher will keep your child's information confidential to the extent allowed by law. Members of the Institutional Review Board (IRB), a university committee charged with reviewing research to ensure the rights and welfare of research participants, may be given access to your child's confidential information.

Your child will be assigned a code number as a way to identify and keep track of data. Numbers assigned to your child with not be associated with his/her name or any other identifying information. This is to ensure that individuals remain unidentifiable. Your child's birth date will be recorded as a way to calculate your child's chronological age in order to interpret scores and results of this study. All information obtained from testing will be kept in Dr. Carter's office secured by lock and key. Only those individuals that YOU choose to share the results with will have access to the results.

Data from this study will be reported in combination with testing information obtained from other participants. None of the participants will be identified in this study by name or birth date.

Voluntary Participation: Your decision to allow your child to participate in this research project is entirely voluntary. If you agree now to allow your child to participate and you change your mind later, you are free to withdraw your child from the study at that time. By not allowing your child to participate in this study or by withdrawing him/her from the study before the research is complete, you are not giving up any rights that you or your child have or any services to which you or your child are otherwise entitled to from Valdosta State University. If you decide to withdraw your child from the study after data collection is complete, your child's information will be deleted from the database and will not be included in research results.

Information Contacts:
Questions regarding the purpose or procedures of the research should be directed to Matt Carter at mdcarter@valdosta.edu. This study has been approved by the Valdosta State University Institutional Review Board (IRB) for the Protection of Human Research Participants. The IRB, a university committee established by Federal law, is responsible for protecting the rights and welfare of research participants. If you have concerns or questions about your child's rights as a research participant, you may contact the IRB Administrator at 229-333-7837 or irb@valdosta.edu.

Parent/Guardian's Initials: _____

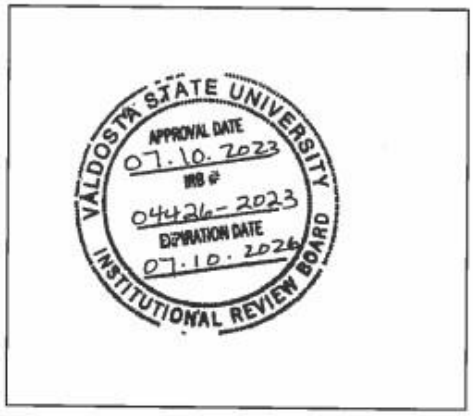
Agreement to Participate: The research project and my child's (or ward's) role in it have been explained to me, and my questions have been answered to my satisfaction. I grant permission for my child to participate in this study. By signing this form, I am indicating that I am either the custodial parent or legal guardian of the child. I have received a copy of this permission form.

I would like to receive a copy of the results of this study: _____ *Yes* _____ *No*

Mailing Address: _____

e-mail Address: _____

This research project has been approved by the Valdosta State University Institutional Review Board for the Protection of Human Research Participants through the date noted below:



_____
Printed Name of Child/Ward

_____
Printed Name of Parent/Guardian

_____
Signature of Parent/Guardian Date

_____
Signature of Person Obtaining Consent Date

Appendix C:

Institutional Review Board Child Verbal Assent Form

Hi. My name is Taylor. I'm a student in college. Right now, I'm doing a research study about how kids read. I would like to ask you to help me by being in a study, but before I do, I want to explain what will happen if you decide to help me.

I will ask you to make sounds, read words, and tell me what letters or numbers that you see. You won't have to answer any questions after you read anything. By being in the study, you will help me understand how kids learn to read.

Your parents will not know what you have said or read. When I tell other people about my study, I will not use your name, and no one will be able to tell who I'm talking about.

Your parent has said that it is okay for you to be in my study. However, if you don't want to be in the study, you don't have to be. What you decide won't make any difference with your grades. I won't be upset, and no one else will be upset, if you don't want to be in the study. If you want to be in the study now but change your mind later, that's okay. You can stop at any time. If there is anything you don't understand you should tell me so I can explain it to you

You can ask me questions about the study. If you have a question later that you don't think of now, you can call me or ask your parents to call me or send me an email.

Do you have any questions for me now?

Would you like to be in my study and read with me?

NOTES TO RESEARCHER: The child (under age 18) must answer "**Yes**" or "**No**." Only a definite "**Yes**" may be taken as assent to participate.

Name of Student: _____ **Parental Permission on File:** ☐ Yes ☐ No

(If "No," do not proceed with assent or research procedures.)

Student's Voluntary Response to Participation: ☐ Yes ☐ No

Signature of Researcher: _____ **Date:** _____

Appendix D:

Individual Participant Data

Summary of Participant TOWRE-2 Scores

Participants	Sight Word Reading	Phonemic Decoding	TOWRE-2 Index
Participant 1	88	66	76
Participant 2	93	87	90
Participant 3	105	99	102
Participant 4	73	71	71
Participant 5	77	87	81
Participant 6	109	102	106
Participant 7	55	72	62
Participant 8	74	71	71
Participant 9	119	116	119
Participant 10	94	80	86
Participant 11	101	82	91
Participant 12	101	106	104
Participant 13	129	126	129
Participant 14	78	74	75
Participant 15	73	73	72
Participant 16	69	75	71
Participant 17	70	70	69
Participant 18	108	119	114
Participant 19	131	138	136
Participant 20	74	80	76

Summary of Participant CTOPP-2 Phonological Awareness Scores

Participants	Elision	Blending	Phoneme Isolation	CTOPP-2 Composite
Participant 1	8	5	6	77
Participant 2	9	8	10	94
Participant 3	8	11	13	105
Participant 4	7	10	10	94
Participant 5	10	10	9	98
Participant 6	12	7	6	90
Participant 7	7	7	8	84
Participant 8	7	6	10	86
Participant 9	11	5	6	84
Participant 10	5	4	4	65
Participant 11	7	8	7	84
Participant 12	13	10	9	105
Participant 13	10	10	10	100
Participant 14	6	6	6	75
Participant 15	6	7	7	80
Participant 16	6	6	7	77
Participant 17	5	6	5	71
Participant 18	10	10	11	103
Participant 19	9	11	10	100
Participant 20	7	13	8	96

Summary of Participant CTOPP-2 RAN Task Scores

Participants	RAN Digit	RAN Letter	RAN Composite
Participant 1	7	7	82
Participant 2	9	9	95
Participant 3	10	10	101
Participant 4	5	7	76
Participant 5	9	10	98
Participant 6	8	7	85
Participant 7	7	5	76
Participant 8	9	10	98
Participant 9	12	8	101
Participant 10	8	7	85
Participant 11	9	7	88
Participant 12	10	7	92
Participant 13	13	12	116
Participant 14	7	8	85
Participant 15	5	3	64
Participant 16	7	7	82
Participant 17	6	8	82
Participant 18	10	10	101
Participant 19	10	9	98
Participant 20	7	7	82

Summary of Participant SART Task Scores

Participants	GO Errors	GO %	NO Errors	NO %	Latency	Mindful
Participant 1	4	86.67%	4	97.0%	762.8	100%
Participant 2	7	76.67%	5	97.4%	741.7	100%
Participant 3	9	70.00%	9	95.3%	739.6	25%
Participant 4	6	80.00%	13	93.23%	799.39	100%
Participant 5	6	80.00%	5	97.40%	742.87	50%
Participant 6	3	90.00%	4	97.92%	532.9	50%
Participant 7	10	66.67%	7	96.35%	872.7	100%
Participant 8	6	80.00%	3	98.44%	645.12	100%
Participant 9	6	80.00%	6	96.88%	728.29	100%
Participant 10	8	73.33%	8	95.83%	745.8	100%
Participant 11	10	66.67%	5	97.40%	733.9	100%
Participant 12	0	100.00%	0	100.00%	648.3	100%
Participant 13	9	70.00%	3	98.44%	714.4	100%
Participant 14	11	63.33%	6	96.88%	813.11	100%
Participant 15	17	43.33%	14	92.71%	871	75%
Participant 16	4	86.67%	8	95.83%	748.46	100%
Participant 17	1	96.67%	1	99.48%	623.52	100%
Participant 18	7	76.67%	10	94.79%	726.6	100%
Participant 19	5	83.33%	17	91.15%	693.92	100%
Participant 20	13	56.67%	3	98.44%	797.82	100%